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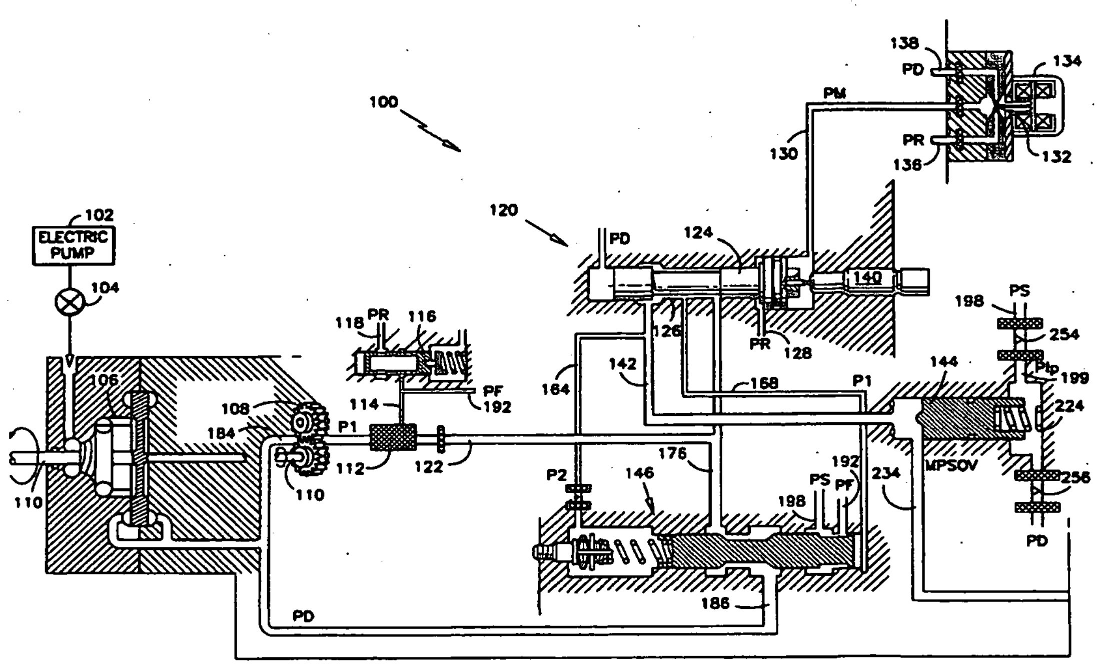

(57) Abstract

A fuel system having a pump (108) for providing a flow of fuel and a metering valve (120) receiving the flow of fuel and providing a regulated flow of fuel consists of a bi-level hydraulic pressurization system for controlling the output pressure of a fuel supply which includes a pressure regulating valve (146) for maintaining a constant pressure differential across the metering valve. The pressure regulating valve also controls a pressure signal to a pressurization valve (144).

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Description

BI-LEVEL HYDRAULIC PRESSURIZING SYSTEM

Technical Field

This invention relates to the control of hydraulic fluid and more particularly to fuel delivery systems for aircraft gas turbine systems.

Background Art

It is well known in the art of fuel delivery systems for aircraft gas turbine engines to use a fixed positive displacement pump, such as a vane or gear pump, to pressurize fuel for subsequent delivery to the engine. The fixed positive displacement pump provides a flow whose volume is a function of the speed at which the pump is rotating. The relation of the change in volumetric output for a change in speed is linear in nature.

The demand for fuel increases as the speed of the turbine increases, although when measured as a function of the percentage of pump output, demand for fuel is greatest at either low speeds (engine start) or at high speeds (take-off). Therefore, in order to provide the desired flow of fuel to the turbine during normal flight operation, the excess fuel output from the fixed positive displacement pump must be bypassed from the fuel control back to the input of the fixed positive displacement pump or to a fuel reservoir.

The positive displacement pump must be sized to ensure an excess flow capacity at all possible operating conditions. Therefore, the pump must be sized for either low speed start conditions, or high speed takeoff conditions.

The speed for greatest fuel demand is unique to each engine and is a function of the minimum starting speed. For engine applications where the

pump has been sized, based on start speed, there will be an excess amount of fuel available at higher speeds.

Today's aircraft manufacturers are moving toward lower engine starting speeds, which tend to drive pump design requirements. As discussed above, sizing pumps for low speed condition generally results in large amounts of bypassed (unused) fuel at higher speed engine operating conditions. This bypassed fuel is continually recirculated and results in significant fuel heating.

With the latest fuel efficient engine designs, excessive fuel heating becomes a serious problem. The increase fuel temperature requires the addition of fuel/oil coolers. Air is also used to reduce fluid temperatures. These devices increase the cost, weight, and fuel burn of the engine.

It is typical in fuel supply systems for aircraft to control the flow of fuel to the engine through the use of a metering valve in conjunction with a pressure regulating valve.

Operation of the metering valve and the pressure regulating valve is based upon incompressible flow theory which states that flow through a valve is a function of the area of the valve opening multiplied by the square root of the product of the pressure drop across the valve multiplied by the specific gravity of the fluid. The pressure regulating valve controls pressure drop across the metering valve and compensates for temperature variations in the fuel, and therefore the flow though the metering valve can be precisely controlled by varying the area of the opening of the metering valve window.

In operation, for a desired increase in engine speed, an electronic controller will position the metering valve for a desired flow of fuel to the engine. The speed of the engine will then increase which in turn drives the positive displacement pump at an increased speed. The increase in pump speed will increase the flow of fuel which will cause a rise in the pressure differential across the metering valve. The pressure regulating valve will then bypass a portion of the fuel output from the positive displacement

pump to maintain the desired pressure differential across the metering valve.

In addition to the fuel required by the engine, the pump also provides a fuel flow having a minimum pressure which is a function of the fuel delivery system hardware. The pressurized fuel is used as a working fluid to position valves within the fuel control. Therefore, the fuel must be maintained at sufficient pressure to position the valves and furthermore must have sufficient pressure to actuate the valves within a required response time (slew rate).

To maintain the engine fuel at a minimum system pressure, a minimum pressurizing valve is positioned downstream of the fuel metering valve in the engine fuel supply path. The minimum pressurizing valve receives the engine fuel flow as an input and is mechanically biased to close at the desired minimum pressure. Therefore, the pressure of the engine fuel flow must be greater than the desired minimum pressure in order to force the minimum pressurizing valve open thus allowing the flow of fuel to the engine.

Higher system pressures increase internal leakage of fuel system components and reduce the volumetric efficiency of the pump thus also increasing pump size.

Disclosure of Invention

An object of the present invention is to reduce the minimum required pump size for starting a turbine engine by reducing the system pressure level during engine start to thereby increase the volumetric efficiency of the fuel pump.

A further object of the present invention is to reduce the minimum required pump size for starting a turbine engine by reducing internal leakage of fuel system components by reducing the system operating pressure during engine start.

A further object of the present invention is to reduce fuel heating by reducing the amount of fuel bypassed during flight mode by minimizing the pump displacement required for proper engine operation.

According to the present invention a fuel delivery system comprises bi-level hydraulic pressure setting valve which maintains the engine fuel pressure at one of two pressures settings. A first pressure setting (start pressure) is maintained during engine start and a second pressure setting (normal pressure) is maintained for all other engine modes, when operating on the minimum pressurizing valve.

The start pressure is determined by the minimum pressure required to provide adequate force margins for valves in the fuel control. This is the minimum pressure required to position the valves in the fuel control for engine start.

The normal pressure is determined by the minimum pressure required to provide proper performance (i.e. slew rate or transfer times) of valves within the fuel control.

In a fuel delivery system having a fuel pump for pressurizing fuel and a metering valve for regulating the amount of fuel delivered to an engine a bi-level hydraulic pressure setting valve preferably comprises a pressure regulating valve and associated orifices and a minimum pressurizing valve. The pressure regulating valve controls the pressure differential across the fuel metering valve and controls the input of a pressure signal to the backside of the minimum pressurizing valve. The minimum pressurizing valve ensures that the minimum fuel system pressure level is maintained.

Fuel is supplied to the metering valve by a fixed displacement pump whose output increases with pump speed. The pressure regulating valve controls the pressure drop across the metering valve to a desired value by bypassing fuel from the metering valve input to the fixed displacement pump input. Prior to engine start, or lightoff, the pressure regulating valve is closed such that no fuel is bypassed and the minimum pressurizing valve is initially biased closed by a spring.

During the engine start, fuel pressure builds and the minimum pressurizing valve opens allowing fuel to flow to the engine. The spring is selected such that the minimum pressurizing valve will open when the fuel pressure is sufficient to overcome the force margins necessary to activate the valves within the fuel control allowing the valves within the fuel control to be positioned for engine start.

As the flow and pressure of the fuel increase, the pressure regulating valve will begin to bypass fuel. This bypassing and associated valve movement opens the pressure signal port to the backside of the minimum pressurizing valve. The pressure signal and associated orifices control the increase in the minimum pressure level between start and normal operation.

A first orifice is located upstream of the minimum pressurizing valve and a second orifice is located downstream of the minimum pressurizing valve. The pressure regulating valve, when bypassing, supplies a pressure/flow source which flows through these orifices resulting in an increase in the minimum pressurizing valve opening pressure. The increase in the minimum pressurizing valve opening pressure causes the fuel system pressure to increase to the minimum level required for proper operating performance of the fuel control valves.

The present invention has the utility of reducing the minimum required pump size for starting a turbine engine by reducing the system pressure setting during engine start.

The present invention also has the utility of increasing the volumetric efficiency of the fuel pump by reducing the operating pressure of the pump upon engine start.

The present invention also has the utility of reducing internal leakage of fuel system components by reducing the system operating pressure at engine start.

The present invention also has the utility of reducing fuel heating by reducing the amount of fuel bypassed during flight mode by reducing the pump requirements for engine startup.

Brief Description of Drawings

FIG. 1 is a schematic view of a fuel delivery system in accordance with the present invention;

FIG. 2 is a cross-sectional view of the pressure regulating/pressure setting valve with pressure setting function during engine start;

FIG. 3 is a cross-sectional view of the pressure regulating/pressure setting valve with pressure setting function during normal engine operation;

FIG. 4 is a cross-sectional view of the minimum pressurizing valve prior to engine start;

FIG. 5 is a cross-sectional view of the minimum pressurizing valve during normal operation.

Best Mode for Carrying Out the Invention

Referring to FIG. 1, there illustrated is a fuel delivery system **100**, preferably for an aircraft engine, according to the present invention. Upon startup or lightoff an electric pump **102** supplies fuel through a solenoid valve **104** to an inducer/boost pump **106** which in turn supplies fuel to the inlet of the positive displacement pump **108**. The solenoid valve **104** and electric pump **102** are controlled by the aircraft pilot.

The positive displacement pump **108**, is driven by a shaft **110** which in turn is driven by the engine (not shown). Therefore, the amount of fuel delivered by pump **108** is a function of engine speed.

The output of the positive displacement pump **108** is input to a fine screen filter **112** which filters out impurities from the fuel. A portion of the filtered fuel (PF) is delivered through line **114** to a servo pressure regulator **116** . The servo pressure regulator produces regulated pressure (PR) on line **118** used for positioning the metering valve **120**. PR is at a higher pressure than the pump interstage pressure (PD) which is the pressure at the inlet **184** of positive displacement pump **108**. PR and PF are two of the

pressure sources used to position valves within the fuel delivery system **100.**

The majority of the fuel is delivered via fuel line **122** to either the metering valve **120** or the pressure regulating/pressure setting valve (PRV) **146.** The metering valve controls the flow of fuel to the engine by positioning spool **124** which in turn controls the area of the metering valve window **126.**

The position of the spool **124** is maintained by two counter balancing pressures, PR on line **128,** and the modulated pressure (PM) input on line **130.** The PM on line **130** is controlled by a flapper valve **132** which is positioned by a torque motor **134** in response to a signal from the electronic engine control (EEC not shown). PM is proportional to PR on line **136** and PD on line **138.**

The EEC determines the desired metering valve **120** position based on the commanded engine speed. Feedback on the position of spool **124** position is provided by an LVDT **140** which is monitored by the EEC. The output of the metering valve **120** is delivered to the minimum pressurizing valve **144** on line **142.** The minimum pressurizing valve **144** sets the inlet pressure of the fuel to be delivered to the fuel control from the positive displacement pump **108.** The function of the minimum pressurizing valve **144** will be described in greater detail herein.

The flow through the metering valve is proportional to the area of the metering valve window **126** multiplied by the square root of the product of the pressure differential across the metering valve window **126** and the specific gravity of the fuel. Therefore, in order for the metering valve **120** to precisely control the flow of fuel to the engine by varying the area of the metering window **126** the pressure drop across the metering valve **120** must be held at a constant set point. The pressure drop across the metering valve **120** is controlled by the pressure regulating pressure setting valve (PRV) **146.**

The PRV **146** is shown in greater detail in FIG. 2. The PRV **146** consists of a housing **148** having a first end **150** and second end **152** and having a cavity **154** disposed through its length. Slidably located within the cavity **154** is a spool **156** having a low pressure end **158** and high pressure end **160**.

Located at the first end **150** of the housing **148** is a port **162** for sensing the metered pressure (P2) of the metered flow on line **164.** Located at a second end **152** of the housing is a second port **166** for sensing pressure (P1) of the positive displacement pump output flow on line **168.** The positive displacement pump output pressure (P1) acts upon the high pressure end **160** of spool **156.** The pressure differential across metering valve **120** is equal to the difference between P1 and P2.

Spring **170** is located within cavity **154** acting upon first end **158** of spool **156.** The spring **170** sets the pressure differential to be maintained across the metering valve **120.** The spring **170** has sufficient force to hold the spool **156** in a closed position, upon startup or lightoff of the engine as shown in FIG. 2. Adjustment screw **175** allows for manual adjustment of the differential pressure to be maintained across the metering valve **120**. The spring **170** is located relative to the housing by spring seat **172.**

Bi-metallic discs **173** act upon the spring seat **172.** The bi-metallic discs **173** expand as the temperature of the fuel increases thus increasing the pressure differential setting across the metering valve. This expansion is needed for this temperature change because the flow through the metering window **126** of valve **120** is proportional to the area of the metering window **126** multiplied by the square root of the product of the pressure drop across the metering window **126** multiplied by the specific gravity of the fuel. The specific gravity of the fuel decreases as the temperature of the fuel increases. Therefore, the pressure differential must be increased for decreases in specific gravity in order to have the expected fuel flow for a given metering window **126** area.

There are four ports located along the length of the housing **148** in fluid communication with the cavity **154**. The first port **174** receives flow from the output of the positive displacement pump **108** along line **176** and is connected to cavity **154** through first window **180.** The second port **182** is an output for providing bypass flow to the inlet **184** of the positive displacement pump **108** along line **186** and is connected to cavity **154** through second window **188.** The third port **190** is an input for receiving PF along line **192** and is connected to cavity **154** through third window **194.** The fourth port **196** is an output for providing pressure signal (PS) on line **198** to the minimum pressurizing valve **144**. The fourth port **196** is connected to cavity **154** through fourth window **200**.

The spool **156** has a first land **202,** a second land **204** and a third land **206**. A first recess **208** separates the first **202** and second **204** lands, and a second recess **210** separates the second **204** and third **206** lands, with the second land **204** being disposed between the first **202** and third **206** lands.

FIG. 2 also shows the PRV **146** in a first, closed position. In this position the force exerted by P1 through line **168** on the high pressure end **160** of the spool **156** is less than the combined force of the spring **170,** bi-metallic discs **173,** and P2 exerted on the low pressure end **158** of the spool **156.** In this position the first land **202** is disposed between the first window **180** and the second window **188** preventing bypass flow to the pump high pressure inlet **184** through line **186.** The second land **204** is positioned between the third window **194** and the fourth window **200** preventing PS flow to the low pressure end **224** of the minimum pressurizing valve **144**, as shown in FIG. 4.

As the speed of the positive displacement pump **108** increases, the pressure P1 increases such that it is greater than the combined force of P2, spring **170** and bi-metallic discs **173** causing the spool **156** to transition to the left as shown in FIG. 3. The first land **202** is now positioned such that

first window **180** is now in fluid communication with second window **188** through first recess **208** allowing bypass flow to the pump high pressure inlet **184.** As the fuel is bypassed the pressure differential across the metering valve **120** will return to the desired set point and the pressure acting upon spool **156** will be balanced.

As the spool **156** (FIG. 3) travels toward the left, the second land **204** is positioned such that the third window **194** and fourth window **200** are in fluid communication allowing PS to communicate with the low pressure end **224** of minimum pressurizing valve **144** as shown in FIG. 4.

The spool and windows of the PRV **146** may be arranged such that the pressure at which fuel is bypassed and the pressure at which PS is ported to the low pressure end **214** of the minimum pressurizing valve **144** may be the same or different.

As the speed of the positive displacement pump **108** decreases, the process described in the preceding paragraphs is reversed.

The minimum pressurizing valve **144** is shown in greater detail in FIG. 4. The minimum pressurizing valve **144** shown in the closed position, consists of a housing **214** having a first end **216** and second end **218** and having a cavity **220** disposed through its length. Slidably located within the cavity **220** is a spool **222** having a low pressure end **224** and high pressure end **226**. The spool **222** also has a drilled passage **231** to reduce weight.

Located at the first end **216** of the housing **214** is a spring **228.** The spring **228** acts upon the low pressure end **224** of the spool **222.** Located at a second end **218** of the housing is a regulated fuel inlet **230** for receiving the metered flow from the metering valve **120** through line **142**. The regulated fuel acts on the high pressure end **226** of the spool **222**.

There are two ports located along the length of the housing **214** in fluid communication with the cavity **220**. The first port **232** is an output to the engine (not shown) along line **234** and is connected to cavity **220**

through first window **236.** The second port **244** is an input for receiving Plp through line **199** and is connected to cavity **220** through third window **246.**

A first orifice **254** is located between the PS **198** and second port **244** and second orifice **256** is located between the second port **244** and PD which is the same pressure as the positive displacement pump inlet **184**. The positive displacement pump **108** outlet pressure is a function of 1) pressure drop across the metering valve **120**; 2) minimum pressurizing valve spring **228**; 3) minimum pressurizing valve **144** cross sectional area; and 4) the ratio of first orifice **254** and the second orifice **256.** The following equation provides a method for calculating the positive displacement pump **108** outlet pressure (P1):

$$P1=(MVDP + Fs/Av)/(1-1/(1+(D2^2/D1^2)^2)$$

Where,

P1 is the positive displacement pump **108** outlet pressure (psid) over drain pressure

MVDP is the metering valve **120** pressure drop (psid)

Fs is the minimum pressurizing valve **144** spring force (lbs)

Av is the minimum pressurizing valve **144** cross-sectional area (in^2)

D1 is the diameter of the first orifice **254** (in)

D2 is the diameter of the second orifice **256** (in)

As stated previously, PF and PR are derived from the output of the positive displacement pump **108** and are used for positioning valves within the fuel delivery system **100.**

In operation, the minimum pressurizing valve **144** acts in concert with the PRV **146** to regulate the pressure of the metered fuel flow to the engine. As discussed in the preceding paragraphs, upon engine start the pressure drop across the metering valve **126** is relatively low therefore the pressure at the high pressure end **160** of the PRV **146** is less than the force exerted by the spring **170** and bi-metallic disc **173** and P2. This causes the spool

156 to be positioned as shown in FIG. 2 preventing PS from flowing to the low pressure end **224** of the minimum pressurizing valve **144.**

Therefore, the pressure of the metered fuel needed to force the spool **222** to the open position as shown in FIG. 4 must be greater than the pressure exerted by the spring **228** and Plp thus maintaining the regulated fuel at the pressure as determined by the spring force of the spring **228** and Plp. As discussed, this pressure is selected to be the minimum needed to position the valves in the fuel control for engine start.

As the engine speed increases, the shaft **110** speed increases which increases the output of the fixed displacement pump **108.** This in turn increases the pressure differential across the metering valve **126.** The pressure P1 at the high pressure end **160** of the PRV **146** is greater than the force exerted by the spring **170** and the bi-metallic disc **173** and P2 on the low pressure end **158** of the PRV **146** causing the spool **156** to translate to the position shown in FIG. 3 allowing PS to flow, through line **198,** to the low pressure end **224** of the minimum pressurizing valve **144**. Thus, the pressure at the low pressure end **224** is now determined by Plp and spring **228.**

Metered fuel flow delivered to the minimum pressurizing valve **144** from the metering valve **120** on line **142** must now have a pressure greater than the combined force of the spring **228** and Plp input through second port **224,** thus maintaining the pressure of the metered fuel flow at a higher minimum pressure. This minimum pressure is selected to meet the slew rate requirements of the valves in the fuel control to allow for normal operation of the engine.

It should be understood by those skilled in the art that obvious structural modifications can be made without departing from the spirit of the invention. Accordingly, reference should be made primarily to the accompanying claims, rather than the foregoing specification, to determine the scope of the invention.

The present invention has the utility of reducing the minimum required pump size for starting a turbine engine by reducing the system pressure setting during engine start.

The present invention also has the utility of increasing the volumetric efficiency of the fuel pump by reducing the operating pressure of the pump upon engine start.

The present invention also has the utility of reducing internal leakage of fuel system components by reducing the system operating pressure at engine start.

The present invention also has the utility of reducing fuel heating by reducing the amount of fuel bypassed during flight mode by reducing the pump requirements for engine startup.

We claim:

Claims

1. A bi-level hydraulic pressurization system for regulating a pressure of a fluid comprising:

a sensing means for sensing a flow rate of the fluid, wherein said sensing means provides a pressure signal when said flow rate of the fluid is greater than a first value; and

a pressurizing means for controlling the pressure of the fluid, wherein said pressurizing means is responsive to said pressure signal for controlling the pressure of the fluid to a first minimum pressure when said flow rate is less than said first value and wherein said pressurizing means controls the pressure of the fluid to a second minimum pressure when said flow rate greater than said first value.

2. The bi-level hydraulic pressurization means of Claim 1 wherein said pressurizing means further comprises a biasing means for setting said first and said second minimum pressures.

3. The pressurizing means of Claim 2 wherein said biasing means comprises a spring for setting said first minimum pressure.

4. The pressurizing means of Claim 3 wherein said biasing means further comprises a means for responding to said pressure signal for setting said second minimum pressure.

5. A fuel delivery system for providing a metered fuel flow to an engine, having a pump providing an unregulated fuel flow for positioning valves within the fuel delivery system comprising:

a metering means for providing the metered fuel flow, said metering means in fluid communication with the pump means for receiving said unregulated fuel flow;

a bypass means for regulating the pressure differential across said metering means by regulating a bypass flow of the unregulated fuel from said metering means to the pump;

a sensing means for sensing said bypass flow wherein said sensing means provides a pressure signal when said bypass flow exceeds a value; and

a pressurizing means for setting the output pressure of the metered fuel flow, said pressurizing means responsive to said pressure signal, wherein said pressurizing means sets the output pressure to a first minimum pressure when said bypass flow is less than said value and wherein said pressurizing means sets the output pressure to a second minimum pressure when said bypass flow is greater than said value.

6. The fuel delivery system of Claim 5 wherein said pressurizing means further comprises a biasing means for setting said first and said second minimum pressures.

7. The fuel delivery system of Claim 6 wherein said biasing means comprises a spring for setting said first minimum pressure.

8. The fuel delivery system of Claim 7 wherein said biasing means further comprises a means for responding to said pressure signal for setting said second minimum pressure.

9. The fuel delivery system of Claim 5 wherein said first minimum pressure is equal to a pressure necessary to overcome a force margin of the valves.

10. The fuel delivery system of Claim 5 wherein said second minimum pressure is equal to a pressure necessary to meet a slew rate requirement of the valves.

11. A fuel delivery system for providing a metered fuel flow to an engine, comprising:

a first pump means for providing an unregulated fuel flow;

a metering means for providing the metered fuel flow to the engine, said metering means in fluid communication with said first pump means for receiving said unregulated fuel flow;

a pressure regulation means for setting a pressure differential across said metering means, said pressure regulation means having a means for sensing a bypass flow of unregulated fuel, wherein said pressure regulation means having a means for providing said bypass flow from said metering means to said first pump means for adjusting said pressure differential, and wherein said pressure regulation means providing a pressure signal when said bypass flow is greater than a first value ; and

a pressurizing means for controlling a pressure of the metered fuel flow wherein said pressurization means is responsive to said pressure signal for controlling said pressure of the metered fuel flow to a first minimum pressure when said bypass flow is less than said first value and wherein said pressurizing means controls said pressure of the metered fuel flow to a second minimum pressure when said bypass flow is greater than said first value.

12. The fuel delivery system of Claim 11 further comprising a biasing means for setting said first and said second minimum pressures.

13. The fuel delivery system of Claim 12 wherein said biasing means comprises a spring for setting said first minimum pressure.

14. The fuel delivery system of Claim 13 wherein said biasing means further comprises a means for responding to said pressure signal for setting said second minimum pressure.

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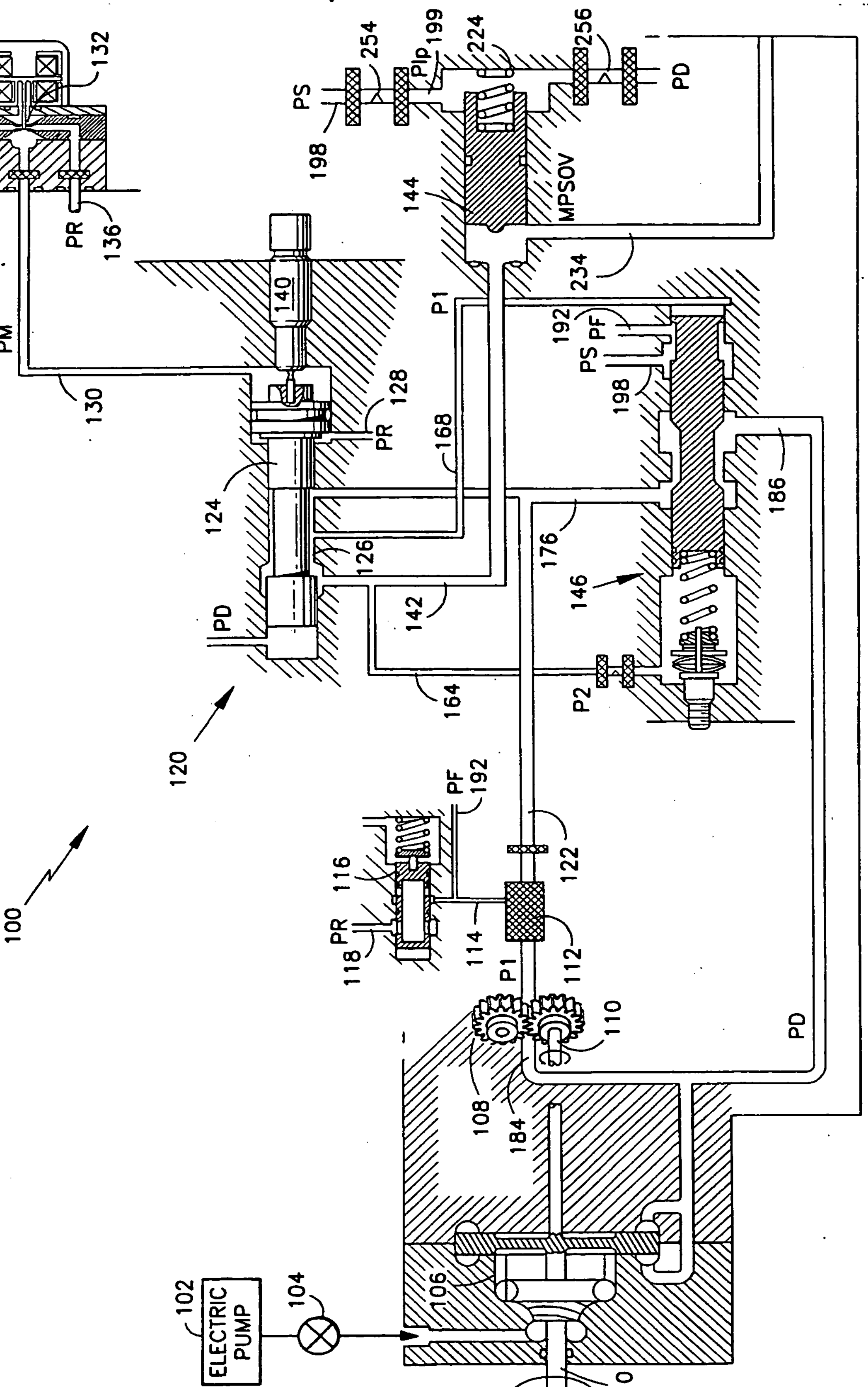

FIG.1

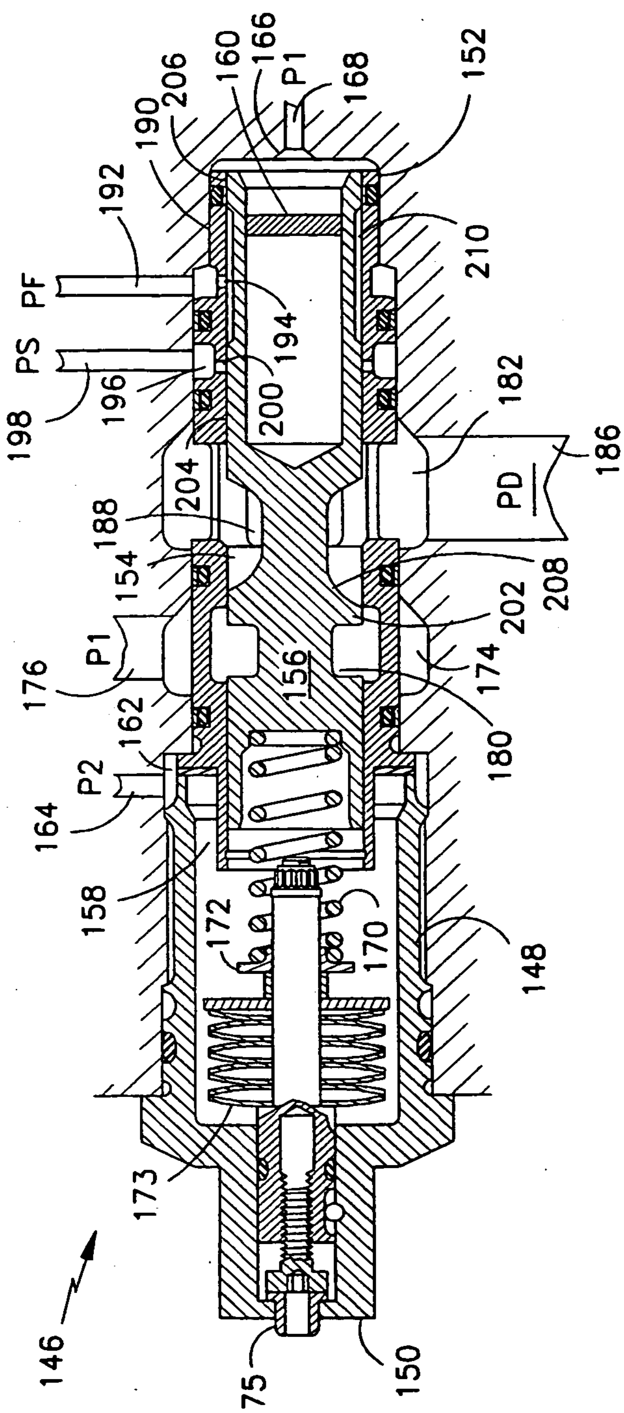

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FIG.2

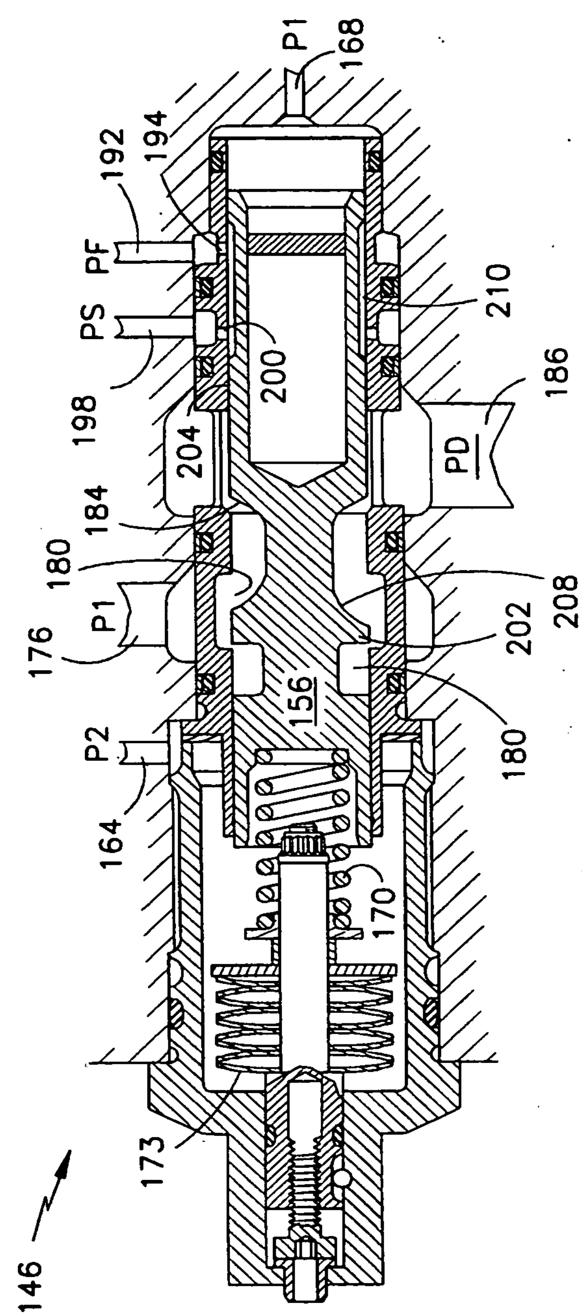

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FIG.3

FIG.4

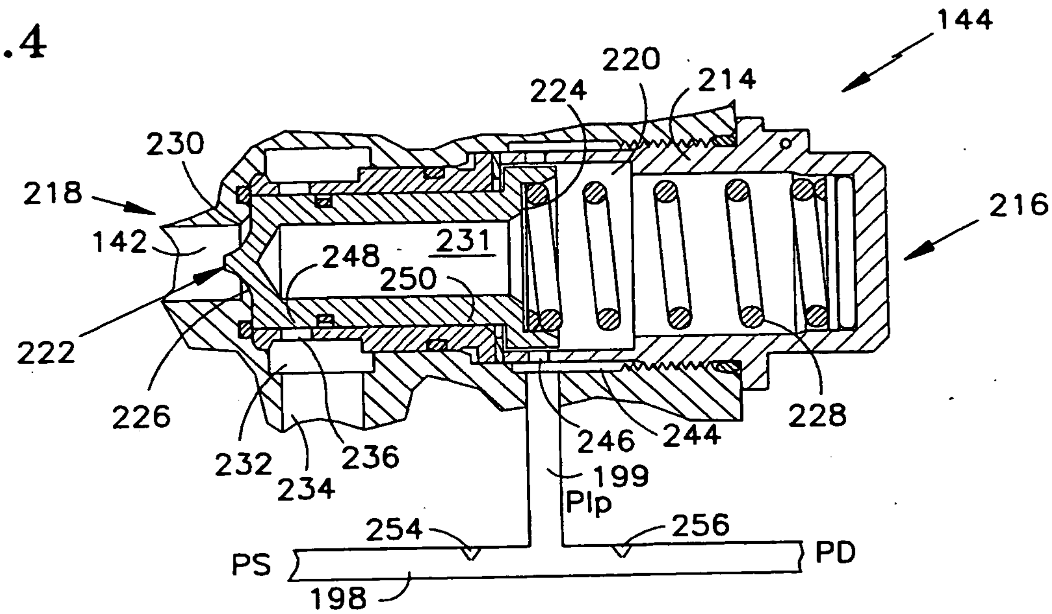
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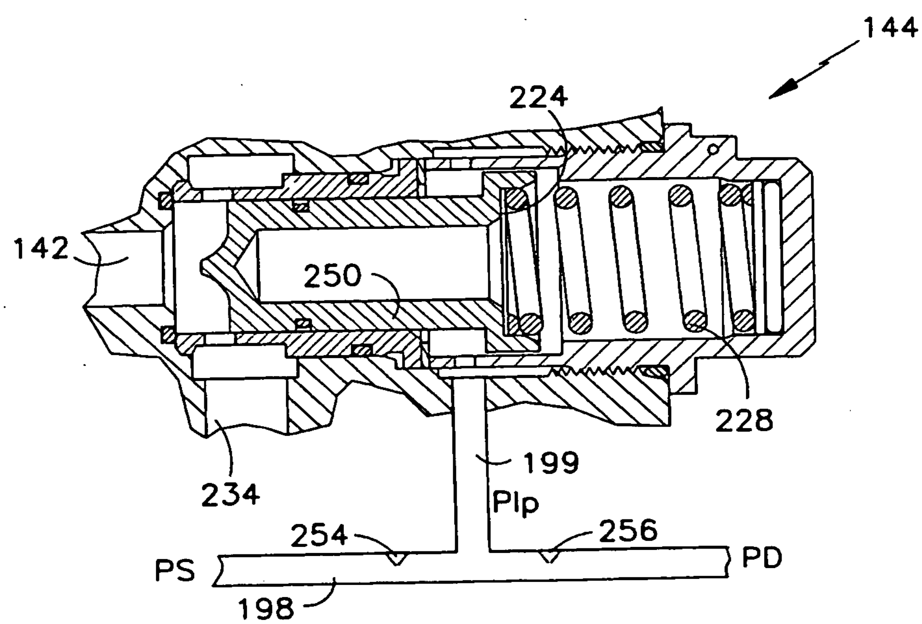
FIG.5


144
224
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Plp
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256
PS
PD
198

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/26897

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :FO2C 9/26
US CL :60/39.281
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 60/39.281, 734

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,808,798 A (TAYLOR) 07 May 1974, see elements 90 and 98.	1-14
Y	US 4,493,187 A (HANSEN) 15 January 1985, see elements 60 and 115.	1-14
Y	US 4,817,376 A (BROCARD et al) 04 April 1989, see element 5.	1-14
Y	US 5,209,058 A (SPARKS et al) 11 May 1993, see elements 70 and 75.	1-14

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 MARCH 1999	04 May 1999 (04.05.99)

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